Oil based fluids - General
Barite sag
Micronized technology

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5.June 2018

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Invert Emulsion Fluids

Oil Based Drilling Fluids (OBM),

Pseudo Oil Based Drilling Fluids (PBM),

Synthetic Oil Based Drilling Fluids (SBM)

=

Invert Emulsion Fluids

=

Non-Aqueous Emulsions

Invert Emulsion Fluids Description

”An invert emulsion mud is a fluid with diesel oil, mineral oil or synthetic fluid as the *continuous phase* and water or brine as an *emulsified (internal) phase.”*

The emulsified water or brine is dispersed within the oil.

$CaCl_2$ brine (most usual brine) is used in the internal phase, in order to increase incorporate formation water from drilled cuttings, and keep water phase salinity to a level where is does not soften or swell water sensitive formations.

Invert Emulsion Fluids – Three Phases

Two immiscible fluids and the solids phase

- ORGANIC FLUID PHASE - continuous - external phase, base oil with lipophilic liquid product additives
- WATER - emulsified droplets as internal phase with a salt – typically $CaCl_2$, and soluble Lime
- SOLIDS – Salt (separated from the water phase during retort analysis), barite (weighting material), organophilic clays, drill solids, insoluble additives - fluid loss control products, LCM, etc.

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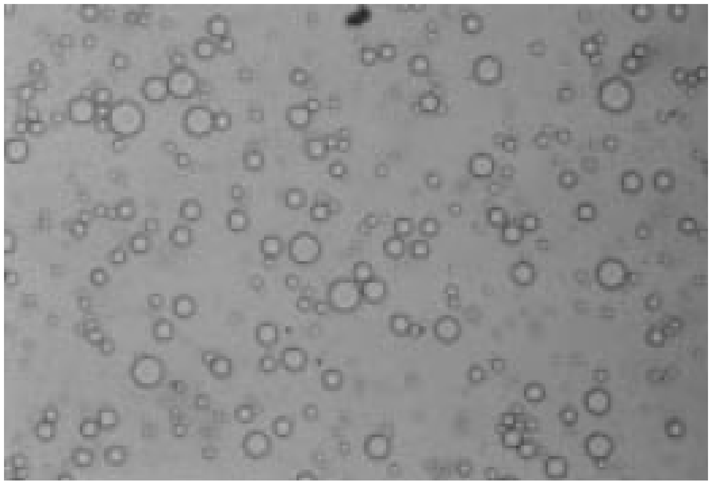
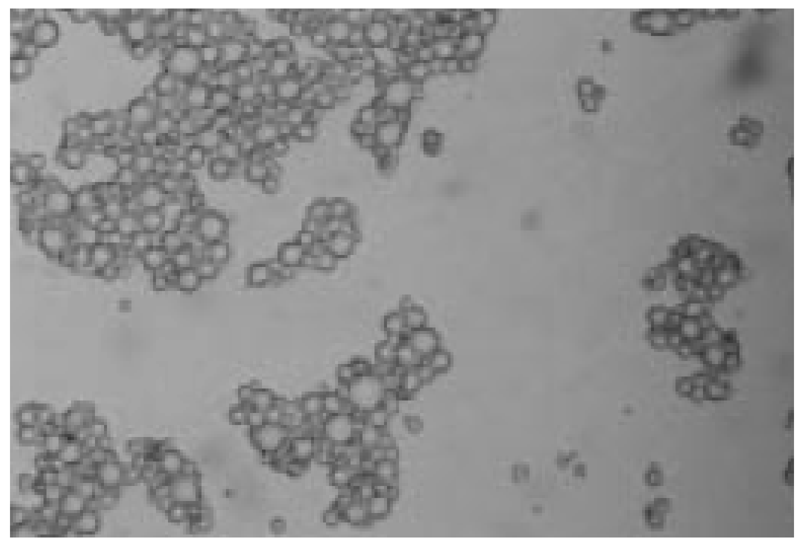
Brine dispersed in oil



Water dispersed in oil

Poorly emulsified water in oil



Invert Emulsion Fluids - Advantages

Highly inhibitive

Shales and reactive formations do not hydrate and swell

Resistant to contaminations

Stable at high temperatures and pressures, HPHT

Provide good lubricity

Non-corrosive

Mineral oils are low-toxic (LTOM)

Wellbore enlagement is reduced

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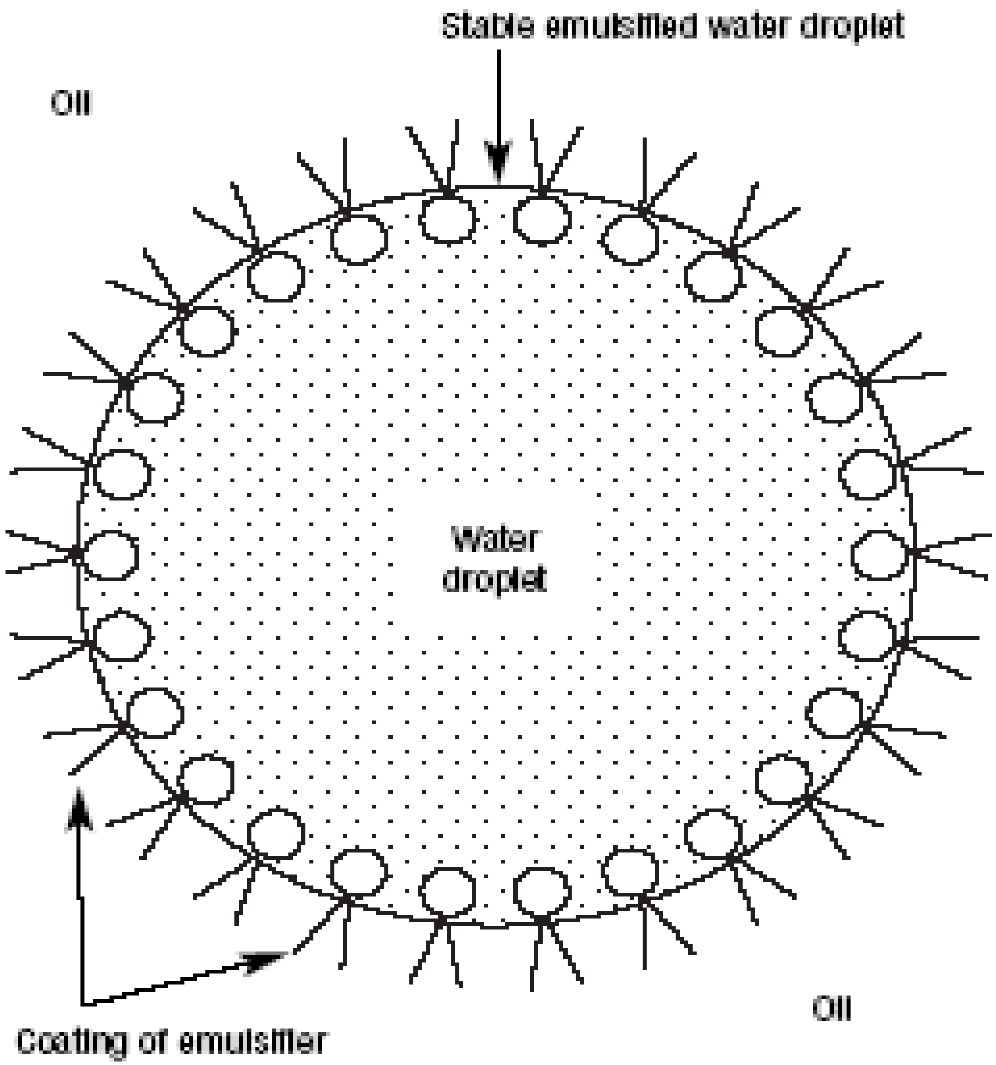
Emulsifiers - Surfactants
Surface Active Agents



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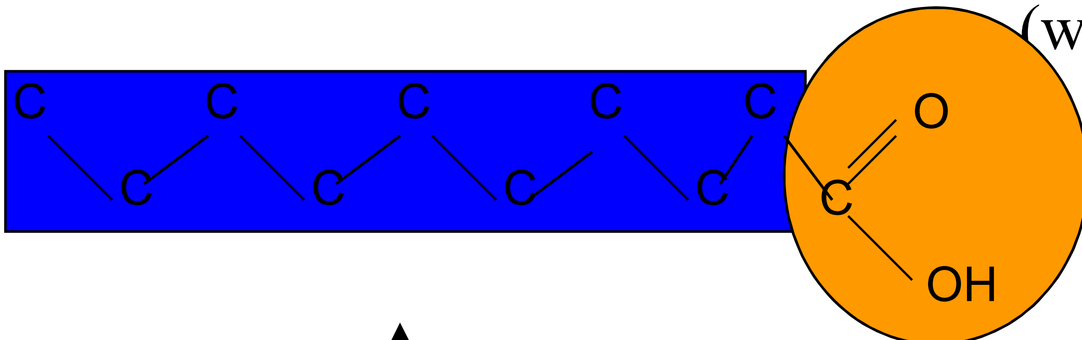
Emulsifiers - Surfactants
Surface Active Agents

Has a hydrophilic polar head

and an organophilic non-polar tail.

Hydrophillic head
(water loving - polar)



Organophillic tail (oil loving – non polar)

Viscosifiers

Clays used in OBM can not be untreated (made oil-soluble), as they will not yield and hydrate.

Clays :

- Need to be coated with an amine to be organophillic
- Will then yield and viscosify.
- In order to achieve maximum yield, water phase is required (-polar activator).

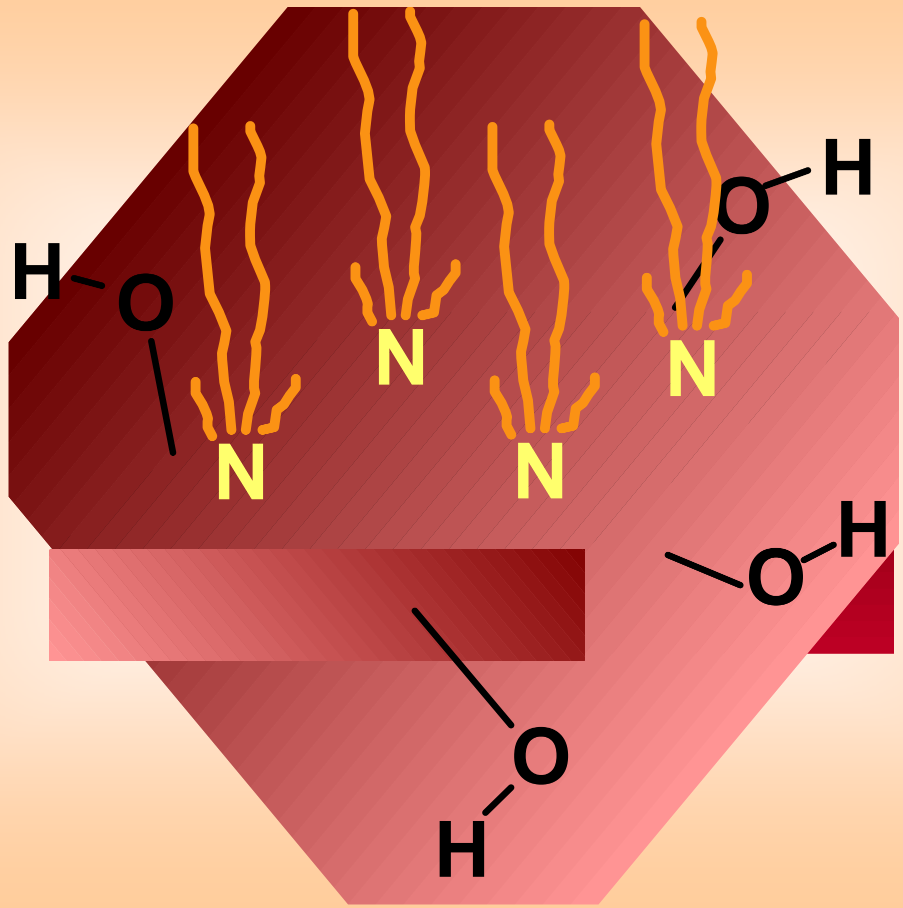
When the OWR increases the yield will decrease

OWR decrease (more water) – yield will increase

Needs Shear and Tempertaure.

Viscosifiers

Organoclay Platelet



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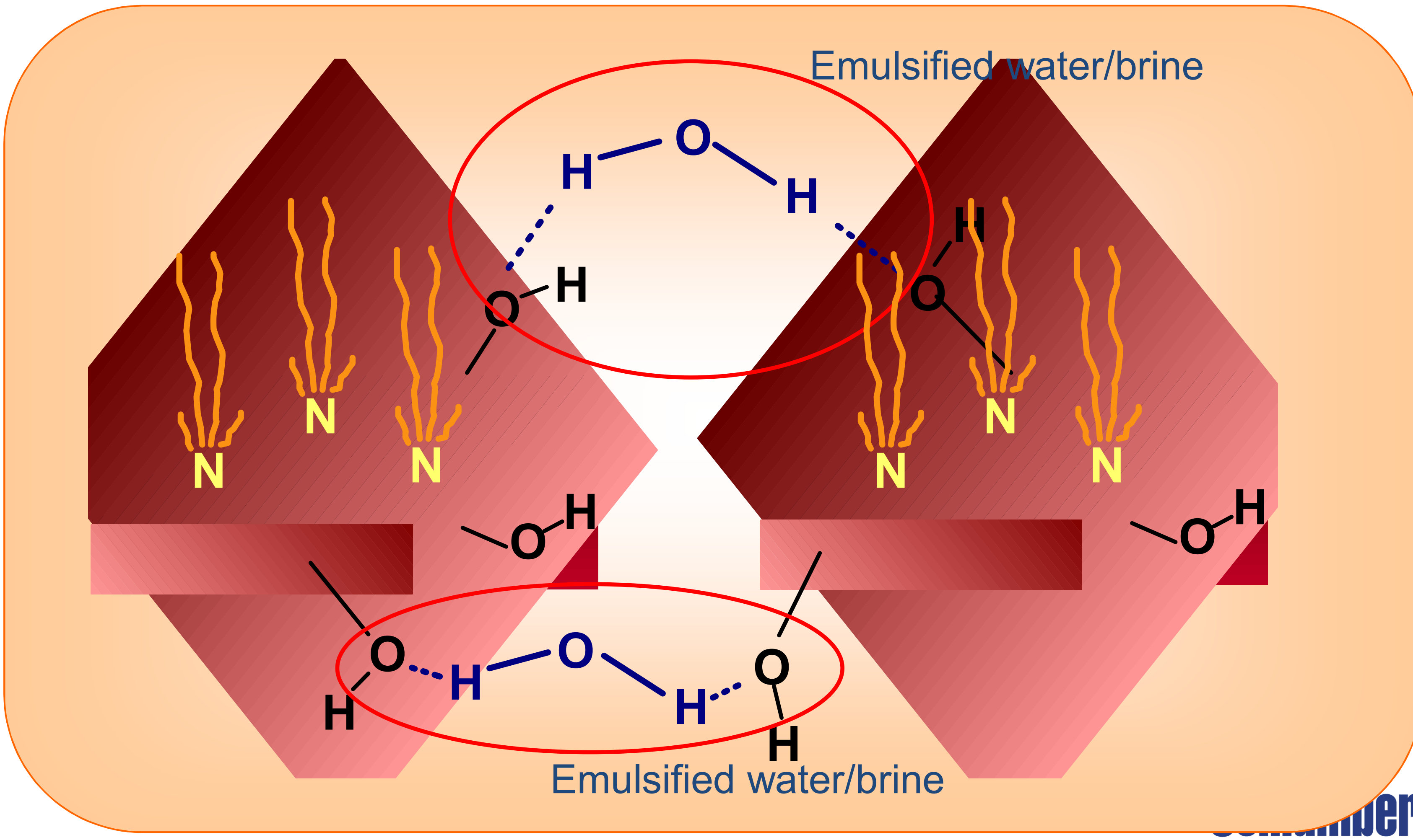
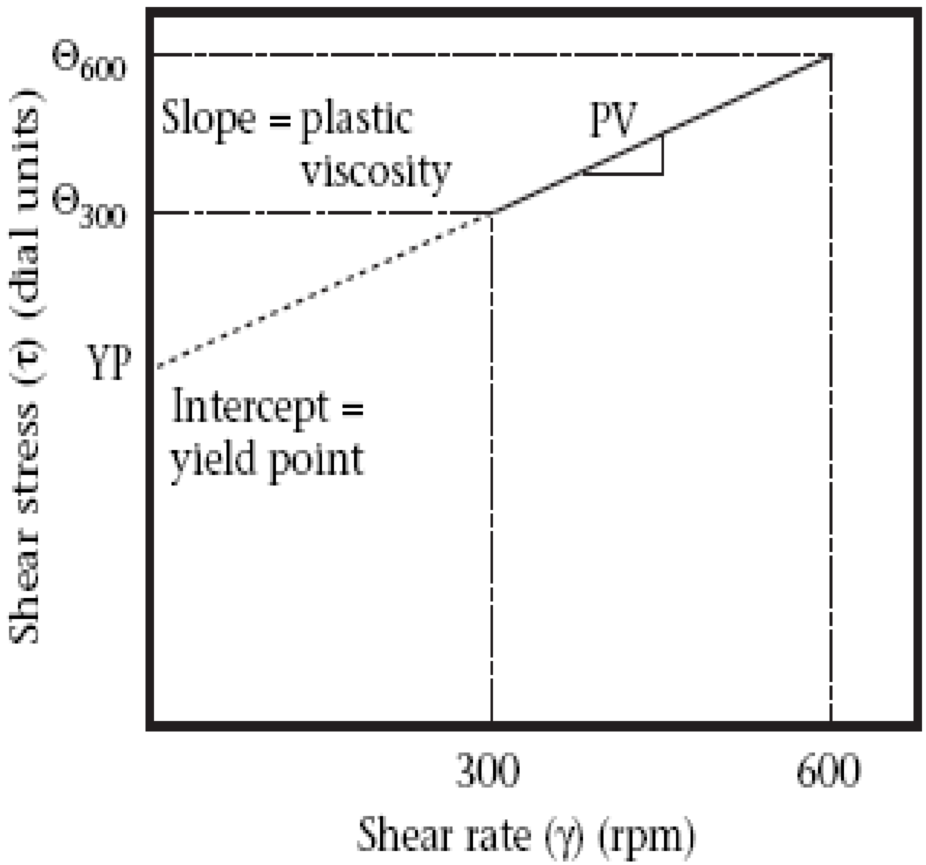
Viscosifiers

Organoclay Gel Mechanism



Bingham Plastic Model

Plastic Viscosity and Yield Point



Fann 35:

600 dial reading	= 40
300 dial reading	= 25
Plastic Viscosity	= 15
Yield Point	= 10

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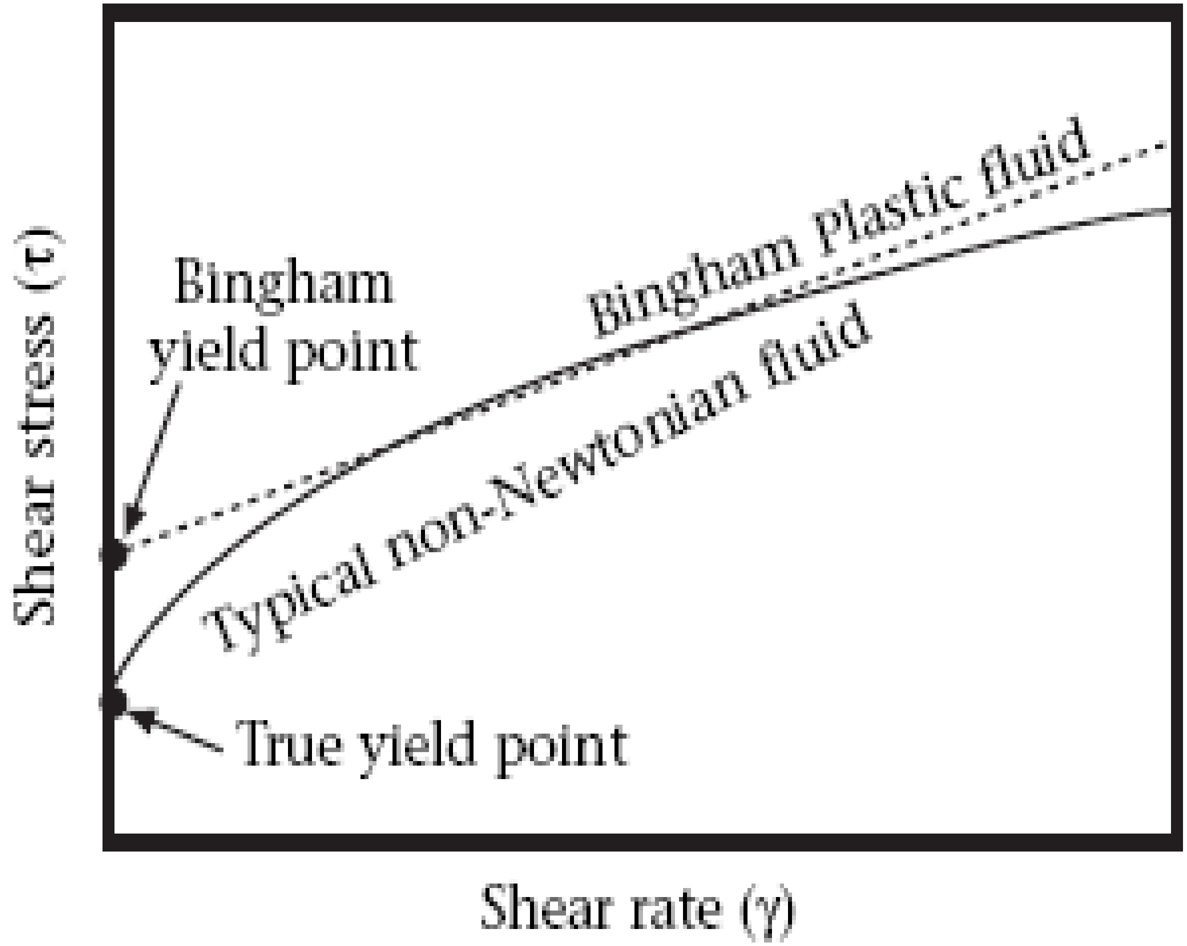
Bingham Plastic Model

True YP = Stress as zero Shear Rate



Fluid Loss Additives

The fluid loss additive's fluid loss effect is a function of:

- Viscosity of continuous phase
- OWR
- Tightness of emulsion
- Water-wetting of the solids
- Amount of amine-treated clay (organo clays)

- Asphaltenic materials
- Polymeric additives

Weight Material

- Barite – Barium sulphate
    - API Barite
    - MicroBar (SLB)
    - WARP Technology (SLB)
- Hematite – Ferrous oxide
- Calcium Carbonate – Chalk/Marble
- Ilmenite – Titanium/Ferrous Oxides
    - MicroDense
- MicroMax – Manganese Oxides

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PSD of the weighting materials

RheGuard (MICROBAR)

d_{10} 0.9 micron

d_{50} 5-8 micron

d_{90} 20 micron

Pneumatic conveyable

OB WARP

d_{10} 0.6 micron

d_{50} 1.6 micron

d_{90} 7.8 micron

Liquid product

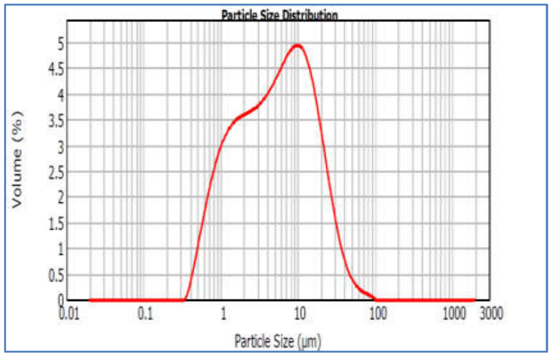
Conv OBM (API Barite)

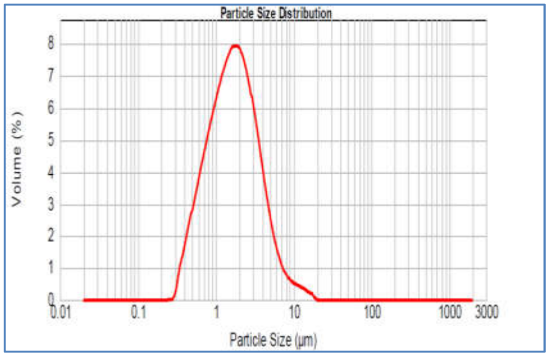
d_{10} 1.8 micron

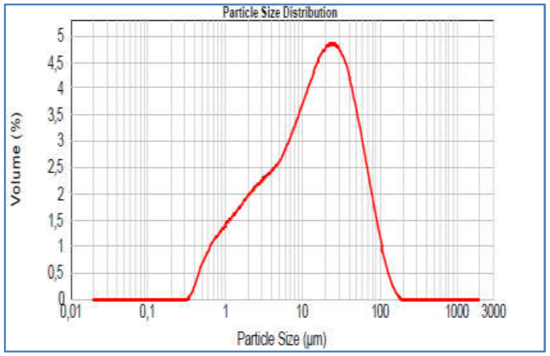
d_{50} 16 micron

d_{90} 55 micron

Pneumatic conveyable







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Oil to Water ratio - OWR

- OWR calculation is not a function of solids content, hence it is not MW dependent
- The ratio of oil and water (determined by retorte evaporation test)
- In order to increase the OWR, base oil must be added on it’s own (need shear), or as a part of a well-sheared premix.
- When the flowline temperatures are high, water evaporation will occur. This will increase OWR.

Oil based fluid – generic formulation

Sequence of addition

FUNCTION	PRODUCTS	CONCENTRATION RANGE, kg/m^3	Mixing time lab, min
Base fluid (Mineral oils)	EDC 95/11, CLAIRSOL NS, SIP 4/0	as needed	
Viscosifier	TRUVIS, BENTONE 128, VG-PLUS, VG-SUPREME, BENTONE 38, VERSAGEL HT	5 - 25	5
Emulsifier/Wetting agent	ONE-MUL, ONE-MUL NS, VERSAWET, SUREMUL PLUS, MEGAMUL, VERSACOAT	15 - 25	5
Alkalinity	LIME	15-20	
Internal phase	CaCl2-BRINE	as needed for salinity	15
Fluid Loss Additive	VERSATROL M, ECOTROL RD, Y-TROL	5 - 25	5
Weighting Agent	API Barite, MICROBAR	as needed for MW	20
Rheology Modifiers (optional)	VersaMod, RheFlat, RheFlat Plus NS	1 - 3	5
Bridging Agent (LGS)	G-SEAL (all grades), SAFECARB (all grades)	10 -150	Paddle in

Questions - OBM

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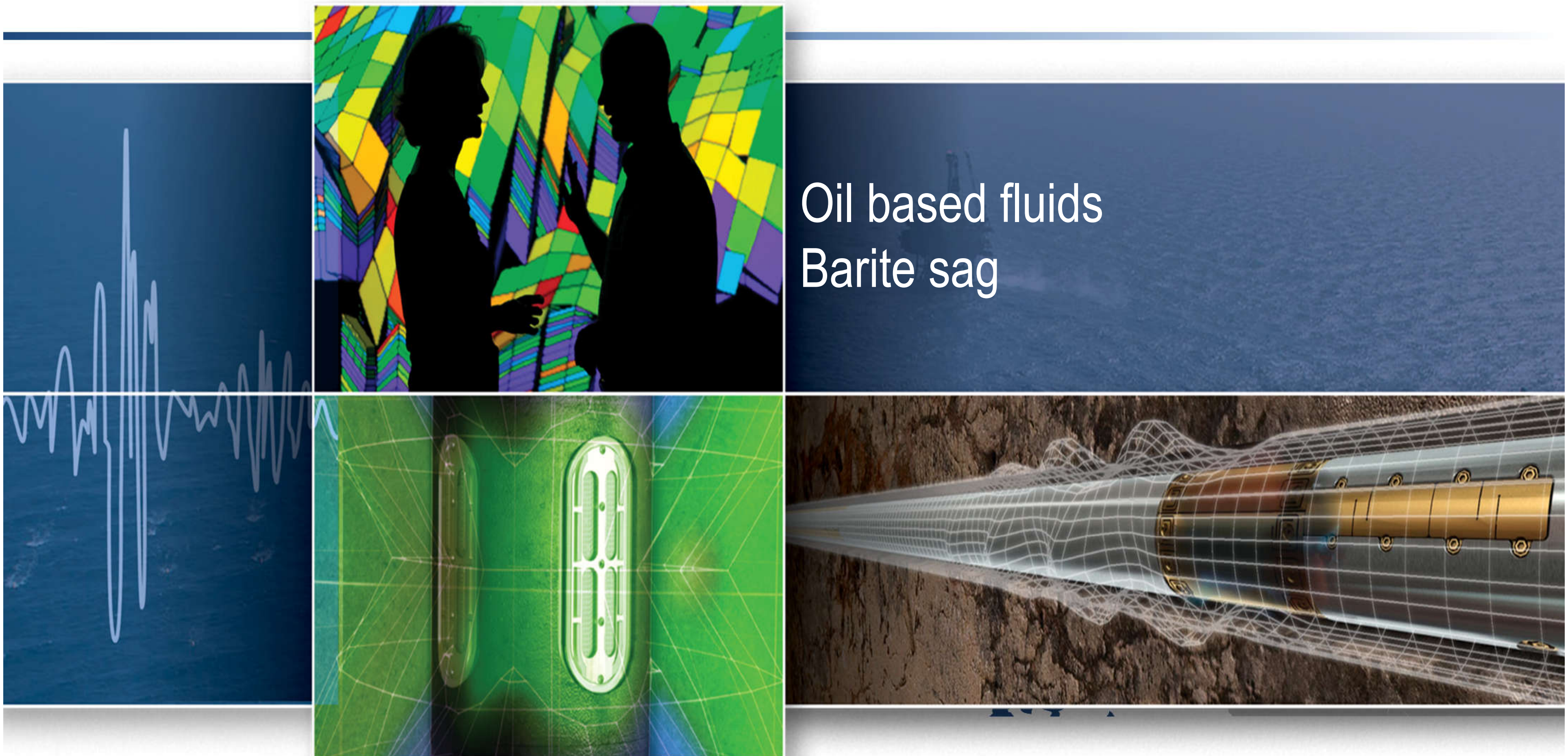
Oil based fluids
Barite sag



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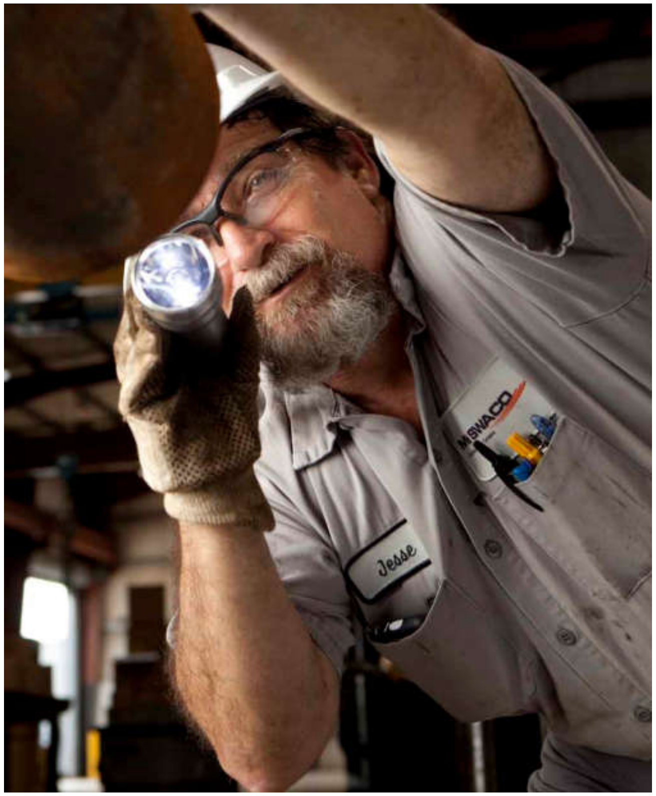
Introduction

Sag is one of the most common problems associated with deviated wells, in particular ERD wells.

Sag-related problems:

- Lost Circulation
- Stuck pipe
- Poor Cement Jobs
- Loss of Well Control
- Loss of Well…



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Barite Sag / Settling

Uneven mud weights on bottoms up after trips:

Variation in mud density

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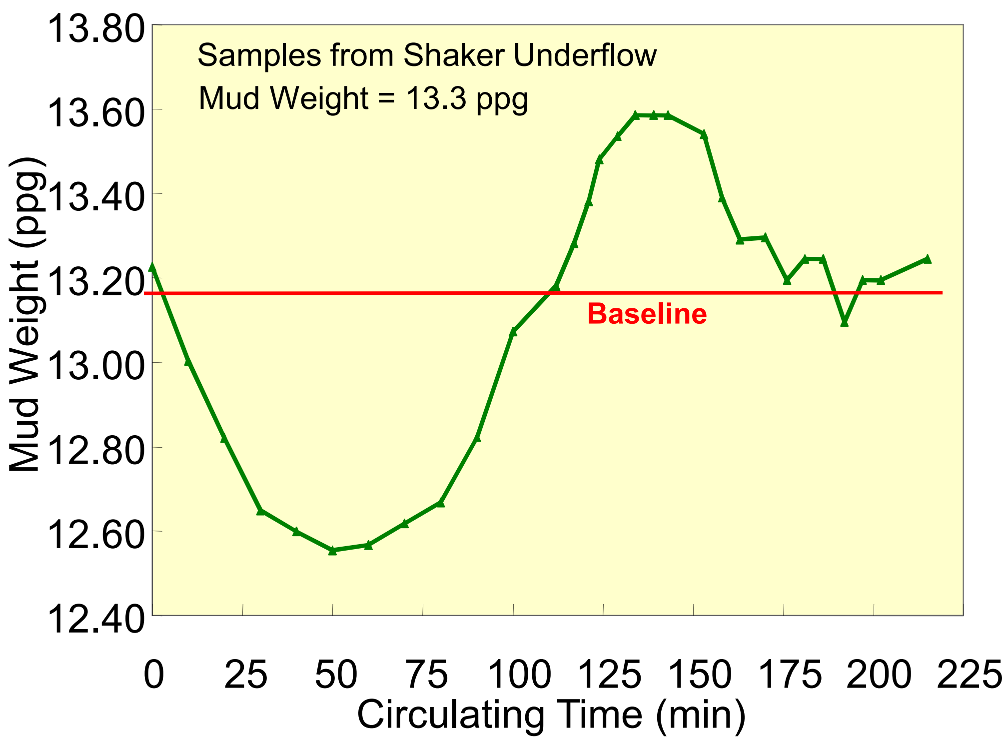
Sag – Definition

- Significant mud density variation - higher <u>and</u> lower than nominal MW - while circulating B/U after a trip or a logging/casing run



- Rheology control – this is when everybody is pointing to the DF company. Organophilic clays are considered more effective sag reducers than fatty-acid-type rheology modifiers.

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Sag Fundamentals

Occurs on directional wells with weighted muds

Primarily a dynamic settling problem

Severity is usually dependent on the length of the static period (trip, logging, casing run)

Can lead to variety of drilling and completion problems

Sag Indicators

Light mud followed by heavy mud when circulating bottoms-up

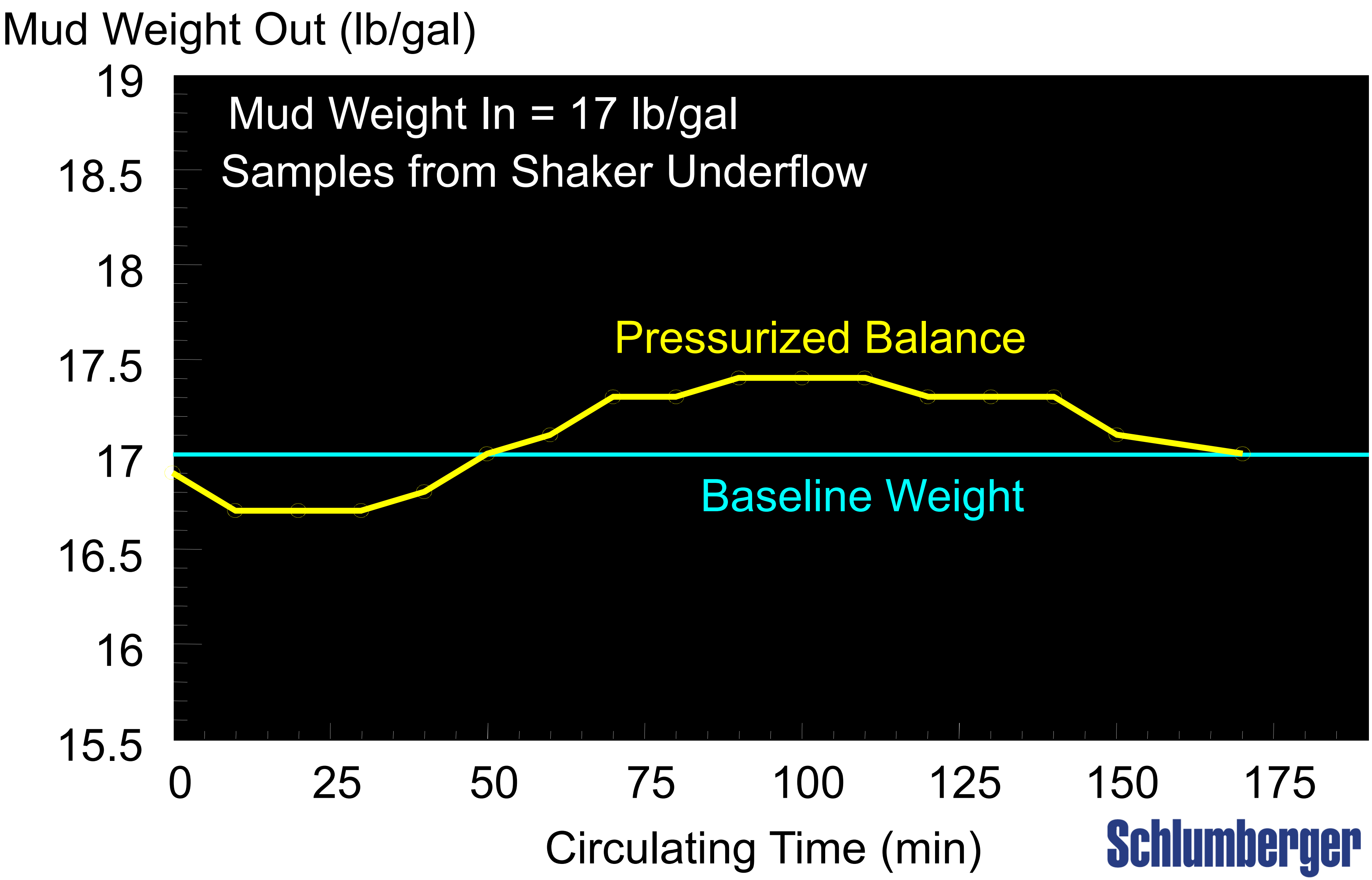
Abnormal standpipe pressures – U tube effect due to heavy mud in annulus

High ECDs, mud losses

High torque and drag – pipe / barite bed contact

Unexpected kicks due to the light mud column

Barite Sag / Settling



Barite Sag / Settling

M-I/Mobil Study (1990) - Barite Sag;

- *Primarily a dynamic settling problem*
- *Minimized by elevating LSRV and gels*
- *Affected by annular velocity and pipe movement*
- *Requires proper mud treatment and operational procedures*

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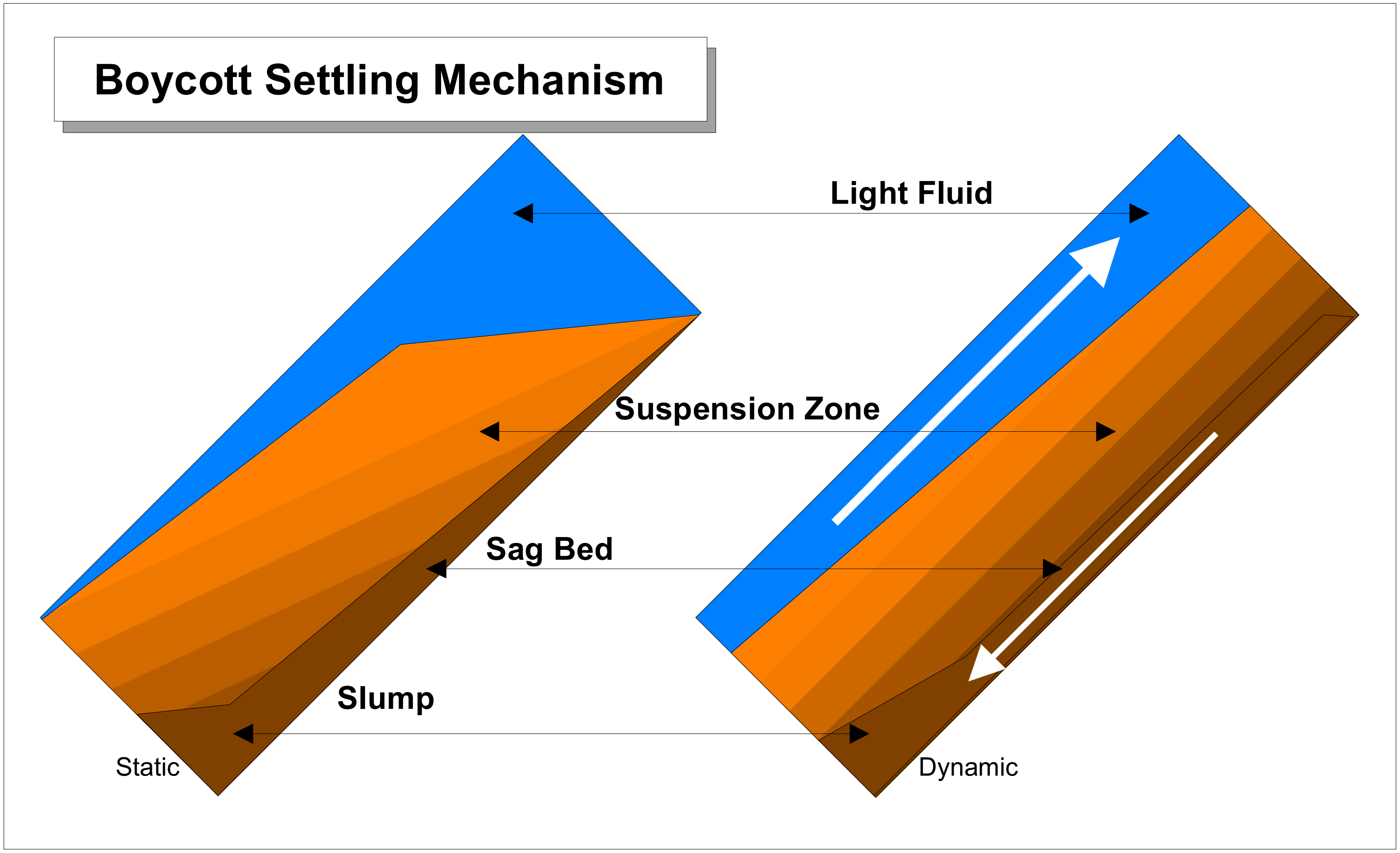
Barite Sag / Settling

M-I/Mobil Study (1990) - Barite Sag;

- *Can lead to common drilling, cementing, logging problems*
- *Can occur in directional wells in all types of weighted muds*
- *Must be systematically checked on trip reports*

Barite Sag / Settling



Barite Sag / Settling

- *Mud sags under dynamic conditions*
- *Sag slumps under any flow conditions*
- *Mud sags and slumps faster at intermediate angles*
- *Sag slumps faster while pumping slowly or tripping*
- *Circulate low MW, then high MW, then regular MW*

Barite Sag / Minimizing Sag; Mud Properties

- *Mud Elevate low-shear-rate viscosity*
- *Improve suspension*
- *Optimize shear to the fluid*
- *Minimize mud thinning*
- *Avoid flocculation*
- *Ensure proper barite wetting in non-aqueous muds*
- *Add premix carefully*

Barite Sag / Minimizing Sag; Operational Properties

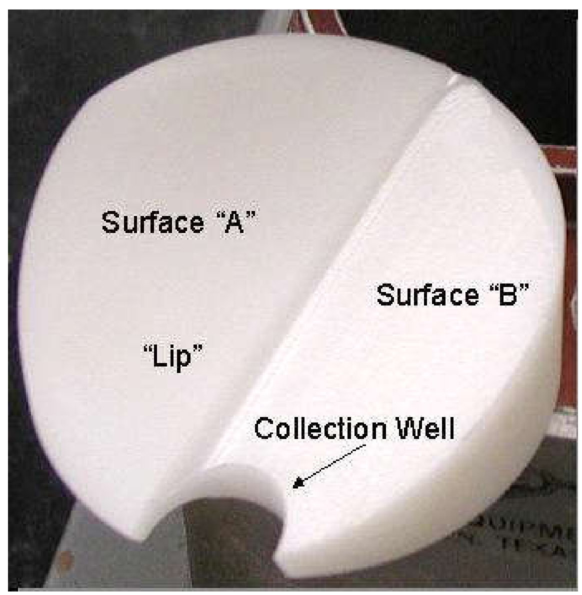
- *Anticipate sag in well planning*
- *Use high annular velocity*
- *Avoid circulating at low flow rates for extended periods*
- *Rotate drill string*
- *Stage to bottom after trips*

Sag Measurement

- Monitor mud weight after trips and when slow-circulating
- Static sag test (lab)
- Dynamic sag test (sag shoe)
- Quantify as ΔMud Wt or Sag Index

Provisional guidelines for sag shoe:

- Use Sag Index.
- Keep ΔMud Wt < 0.7ppg (0.08 s.g.)



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Sag Index for VSST (Sag Shoe test)

- The sag index attempts to normalise the sag reading by taking into account the hole angle, the annular velocity, the rotary speed and the length of hole section
- Sag Index = VSST * Ka*Kv*Kr*Kz

Hole Angle (deg)	Ka
<5	0
5-10	0.03
10-30	0.3
30-40	0.7
40-70	1
70-80	0.8
80-90	0.6

Ann Vel (ft/min)	Kv
<2	1
2-50	1.2
50-100	0.9
100-150	0.6
150-250	0.3
>250	0.1

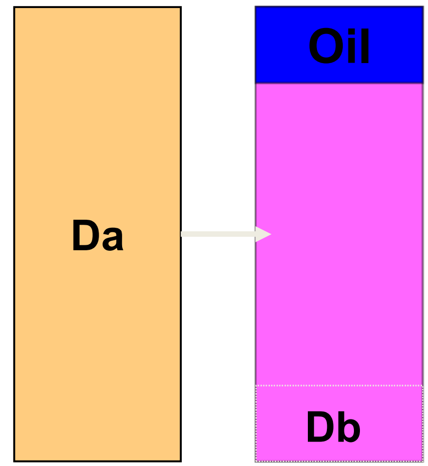
Rotary Speed (rpm)	Kr
<5	1
5-75	1.1
75-100	0.8
100-150	0.5
>150	0.3

Length (ft)	Kz
<1000	0.5
1000-2000	0.7
2000-5000	1
>5000	1.2

- Ref: OMC Paper 105-2009

Static sag measurement in the lab

Static age testing in bombs



ΔMud Wt =
Da - Db

Static age bomb test: reproducibility is poor.

Does not replicate field performance

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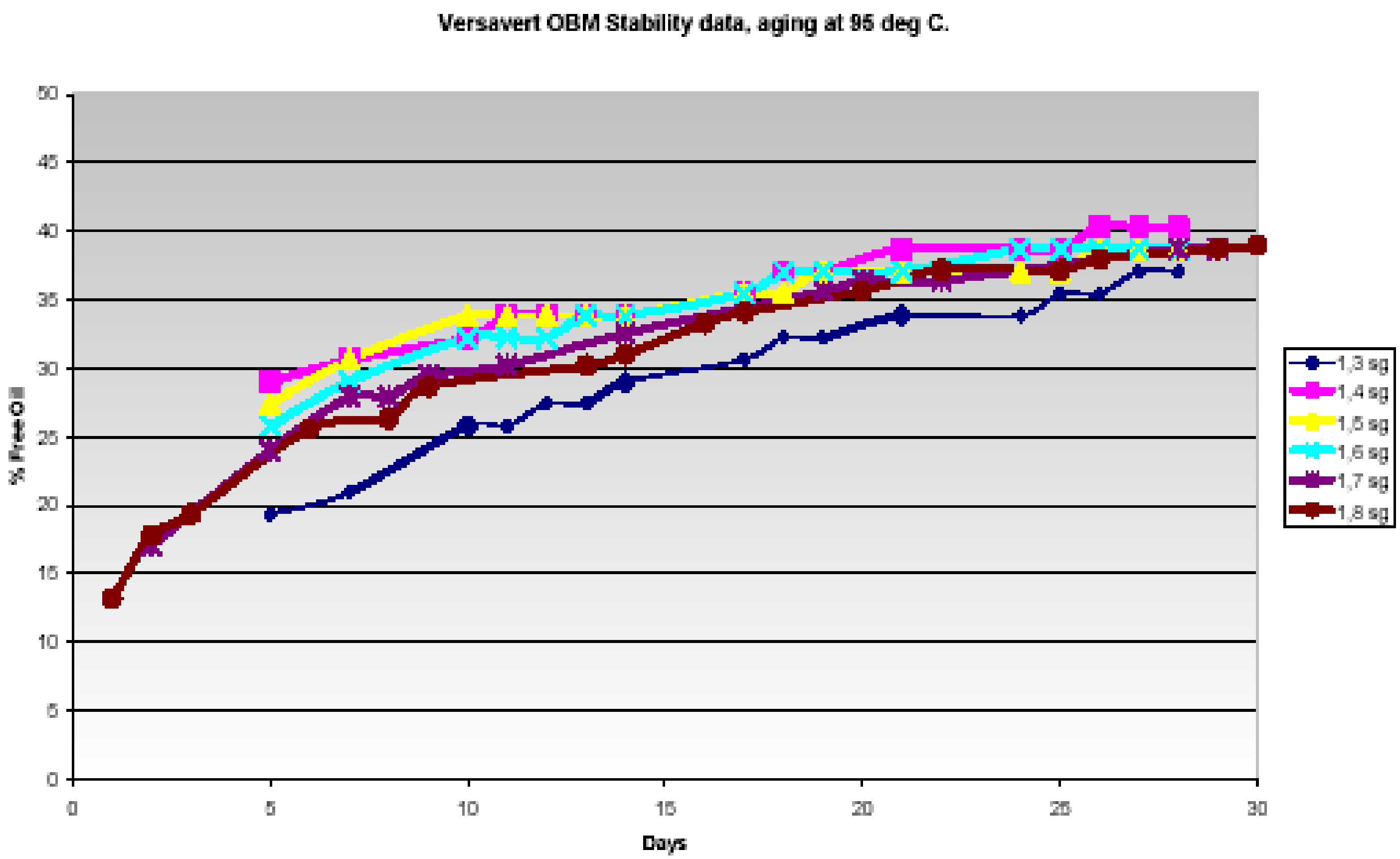
OBM – Free oil separation vs. time at 95^{o}C



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Sag Measurement – Flow Loops

- Measures circulating density at various AV and RPM
- Allows varying angle and eccentricity
- Window for sampling the barite bed
- Electronic data acquisition allows accurate analysis
- Excellent tool to evaluate sag tendency

Test Section

- 44mm or 70mm diameter* 2 m test section with 30 mm stainless steel shaft
- Removable windows for sampling sag bed

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Publications (< 2009)

2009 Enhanced Drilling Performance in High Density Applications by Utilization of an Optimised Drilling Fluid
O.I. Prebensen, D. Oakley, J. Massam,
Offshore Mediterranean Conference and Exhibition in Ravenna, Italy, March 25-27, 2009.

2009 SPE 119567: Successful Drilling of a Deviated, Ultra-HTHP Well Using a Micronised Barite Fluid
Michel Gregoire, SPE, TOTAL E&P UK; Mike Hodder, SPE, Shuangjiu Peng and Jarrod Massam, M-I SWACO
SPE/IADC Drilling Conference and Exhibition held in Amsterdam, The Netherlands, 17–19 March 2009.

2009 SPE/IADC 119212: Improve Drilling Performance by Controlling Risk and Reducing Non-Productive Time in a Challenging High-Temperature, High-Pressure Well
Ole Iacob Prebensen, SPE, Svennung Vidvei, SPE, Gunvald Nesheim, M-I SWACO; Reagan James, SPE,
SPE/IADC Drilling Conference and Exhibition held in Amsterdam, The Netherlands, 17–19 March 2009.

2007 AADE-07-NTCE-23: The Design of High Performance Drill-In Fluids with a View to Maximizing Production and Minimizing Cost
Louise Roedbro and Andrew Stewart, Maersk Oil North Sea UK Limited, Shuangjiu Peng, Mike Hodder & Jarrod Massam,
AADE National Technical Conference and Exhibition held at the Wyndam Greenspoint Hotel, Houston, Texas, April 10-12, 2007.

2008 IADC/SPE 112620: How Effective Is Current Solids Control Equipment for Drilling Fluids Weighted with Micron-Sized Weight Material?
Jarrod Massam, Shannon Stocks, Doug Oakley, Colin Bremner M-I SWACO
IADC/SPE Drilling Conference held in Orlando, Florida, U.S.A. , 4–6 March 2008.

2008 IADC/SPE 112529: Reducing Risk by Using a Unique Oil-Based Drilling Fluid for an Offshore Casing Directional Drilling Operation
Reagan James, SPE, ConocoPhillips Company Norge AS, Ole Iacob Prebensen, SPE, Øystein Randeberg, M-I SWACO
2008 IADC/SPE Drilling Conference held in Orlando, Florida, U.S.A., 4–6 March 2008.

2007 SPE/IADC 105730: Lubriucants Enabled Completion of ERD Well
Jonny Holand, Svein Arne Kvamme, Tor Henry Omland, Arild Saasen, Knut Taugboul, Statoil, John Jamth, Intertek West Lab
2007 SPE/IADC Drilling Conference held in Amsterdam, The Netherlands, 20-22 February 2007

2007 SPE 107802: Formation Damage Observations on Oil-based Fluid Systems Weighted with Treated Micronized Barite
Nils Kågeson-Loe. Russell Watson, Ole Iacob Prebensen /M-I SWACO, Claas Van Der Zwaag, Knut Taugbøl /Statoil ASA
European Formation Damage Conference held in Scheveningen, The Netherlands, 30 May–1 June 2007

2007 SPE/IADC 105487- PP: Field Result of Equivalent Circulating Density Reduction with a Low-Rheology Fluid
Bolivar N., SPE, Young J., SPE, Hibernia Management and Development Company Ltd.; Dear S. (ret.), SPE, ExxonMobil Development Company; Massam J., Reid T, M-I SWACO
2007 SPE/IADC Drilling Conference held in Amsterdam, The Netherlands, 20–22 February 2007.

2006 AADE-06-DF-HO-27: Specially Treated Drilling Fluid Weighting Agent Facilitates Development of Maturing Reservoirs
Doug Oakley, M-I SWACO
AADE 2006 Fluids Conference held at the Wyndam Greenspoint Hotel in Houston, Texas, April 11-12, 2006.

2005 SPE 96285: Development and Field Testing of a Unique High-Temperature/High-Pressure (HTHP) Oil-Based Drilling Fluid With Minimum Rheology and Maximum Sag Stability
K. Taugbøl, G. Fimreite, and O.I. Prebensen, M-I Swaco, and K. Svanes, T.H. Omland, P.E. Svela, and D.H. Breivik, Statoil
Offshore Europe 2005 held in Aberdeen, Scotland, U.K., 6–9 September 2005.

2004 AADE-04-DF-HO-21A Unique Technical Solution to Barite Sag in Drilling Fluids
Jarrod Massam, Andy Popplestone, and Andrew Burn, M-I SWACO
AADE 2004 Drilling Fluids Conference, held at the Radisson Astrodome in Houston, Texas, April 6-7, 2004.

2004 IADC/SPE 87128: Invert Emulsion Fluids for Drilling Through Narrow Hydraulic Windows
Gunnar Fimreite, SPE, Arne Asko, Jarrod Massam, SPE and Knut Taugboul, M-I Norge AS; Tor Henry Omland, SPE, Kaare Svanes, Wenche Kroken, Espen Andreassen, SPE and Arild Saasen, SPE, Statoil ASA
IADC/SPE Drilling Conference held in Dallas, Texas, U.S.A., 2-4 March 2004

Questions - Sag

?

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Micronized technology

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5.June 2018

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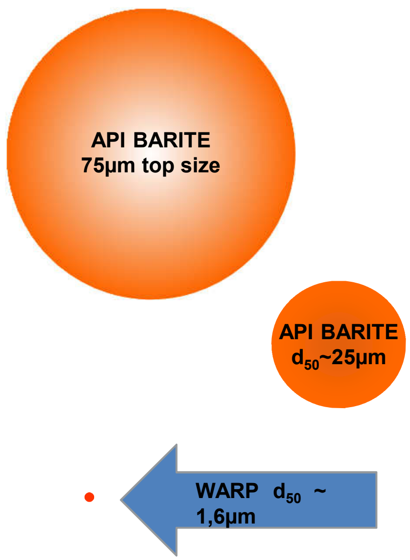
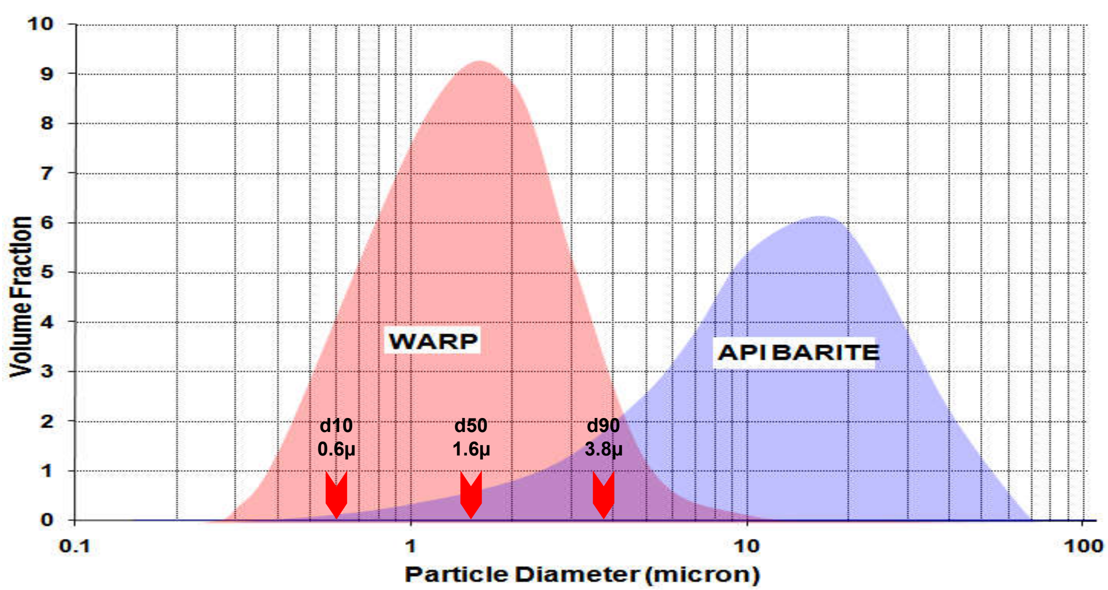
WARP Fluids Technology – Micronized weighting material

- WARP is produced by grinding Barite or other weighting agents in non-aqueous base fluids or brine to produce high density WARP concentrate which can then be diluted and mixed with other products to specification.
- WARP Fluids Technology utilizes chemical treated micronized weighting agents for drilling and completion fluids





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WARP Fluids Technology – Micronized weighting material

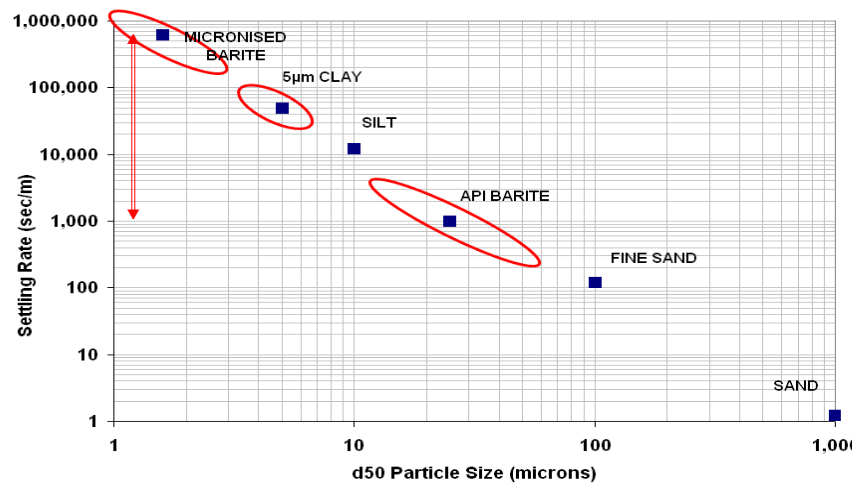
<u>Stokes Law:</u>

A 10 times reduction in particle size,

reduces settling rates by a 100

$$V_s = \frac{2}{9}\frac{(\rho_p - \rho_f)}{\eta} g\, R^2$$

Vs	settling velocity
ρp	particle density
ρf	fluid density
η	fluid viscosity
R	radius of particles



- Reduced risk of MW fluctuations
- Reduced risk of loss of hydrostatic column
- Reduced risk of dynamic sag with low circulation rates

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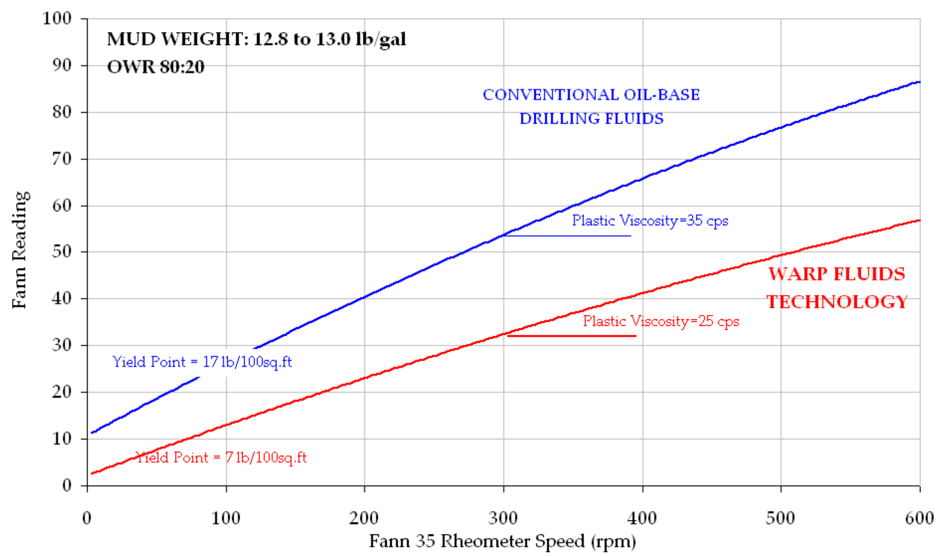
WARP Fluids Technology – Micronized weighting material



- Low 6 and 3rpm values of < 3 Fann-35 Units
- Low Plastic Viscosities and Yield Points
- Reduced ECD's in narrow mud weight windows
- Reduced ECD induced losses
- Reduced pump pressures for the same flow rate
- Reduced swab and surge pressures
- Faster pipe running speeds
- Improved cement job quality – cement displacement fluid.
- Improved MWD/LWD data quality

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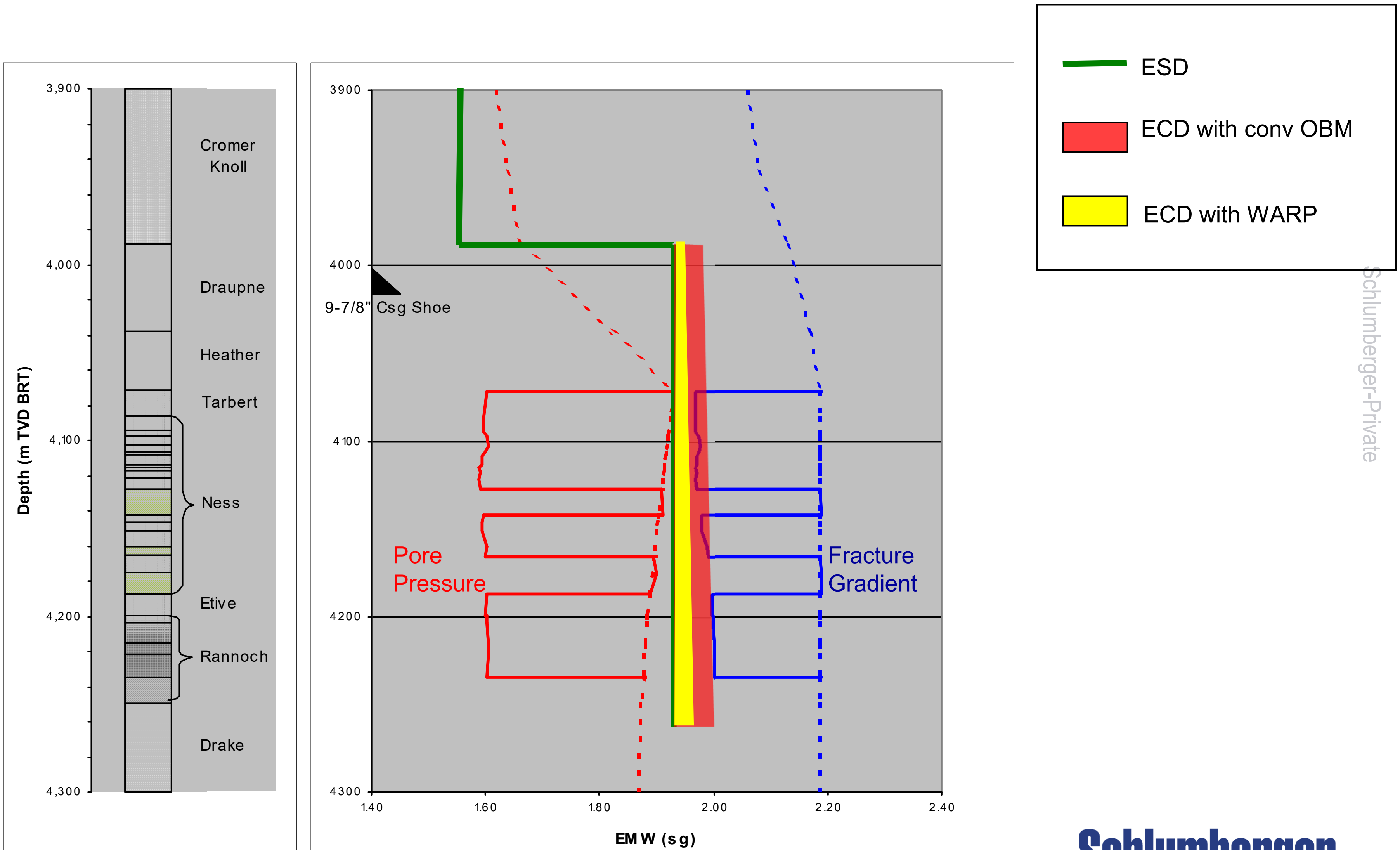
WARP Fluids Technology – Micronized weighting material



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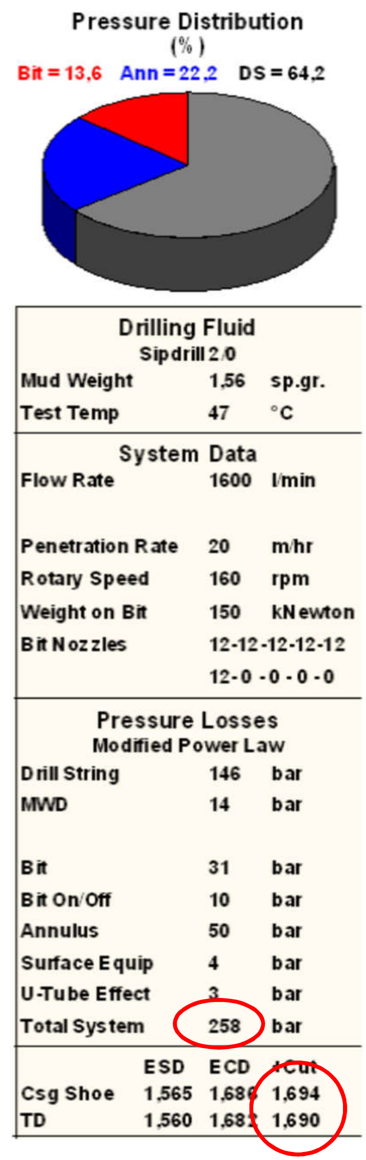
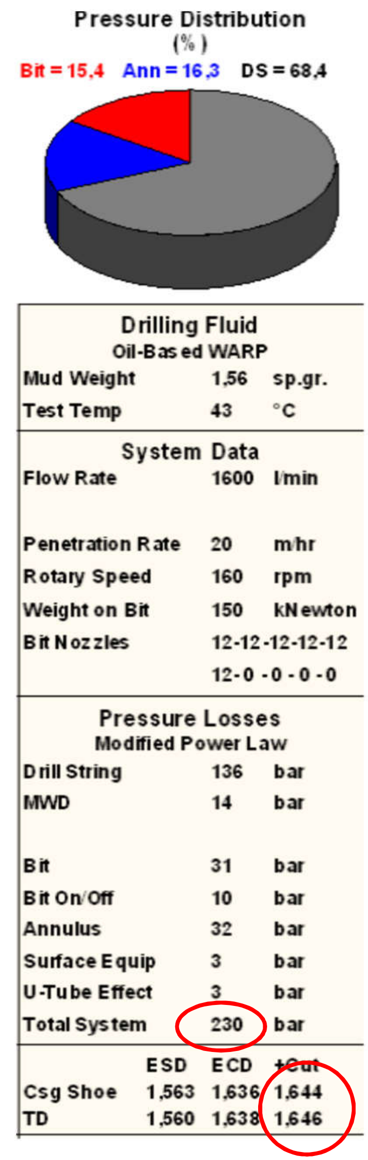
WARP Fluids Technology – Micronized weighting material

Mudsystem 1.56 SG	Conv OBM 1.56 SG	WARP 1.56 SG
Fann-35 600 rpm	87	58
Fann-35 300 rpm	53	33
Fann-35 200 rpm	40	23
Fann-35 100 rpm	26	13
Fann-35 6 rpm	12	3
Fann-35 3 rpm	11	2





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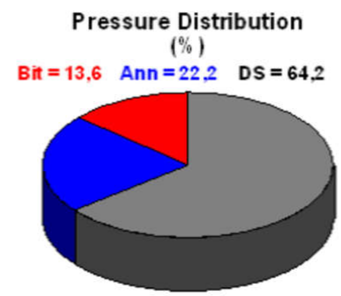
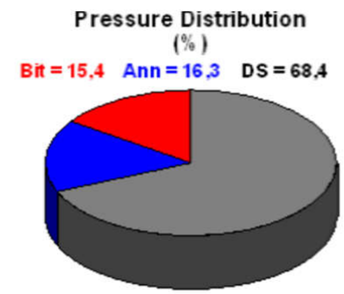


Drilling Fluid		
Sipdrill 2.0		
Mud Weight	1,56	sp.gr.
Test Temp	47	°C
System Data		
Flow Rate	1600	l/min
Penetration Rate	20	m/hr
Rotary Speed	160	rpm
Weight on Bit	150	kNewton
Bit Nozzles	12-12-12-12-12	
	12-0 -0 - 0 -0	

Surface Equip	4	bar	
U-Tube Effect	3	bar	
Total System	258	bar	
	ESD	ECD	+Cut
Csg Shoe	1,565	1,686	1,694
TD	1,560	1,682	1,690



Drilling Fluid		
Oil-Based WARP		
Mud Weight	1,56	sp.gr.
Test Temp	43	°C
System Data		
Flow Rate	1600	l/min
Penetration Rate	20	m/hr
Rotary Speed	160	rpm
Weight on Bit	150	kNewton
Bit Nozzles	12-12-12-12-12	
	12-0 -0 - 0 -0	

Surface Equip	3	bar	
U-Tube Effect	3	bar	
Total System	230	bar	
	ESD	ECD	+Cut
Csg Shoe	1,563	1,636	1,644
TD	1,560	1,638	1,646

WARP Fluids Technology – Micronized weighting material

Small particle size
WARP Fluids

Low Viscosity
WARP Fluids

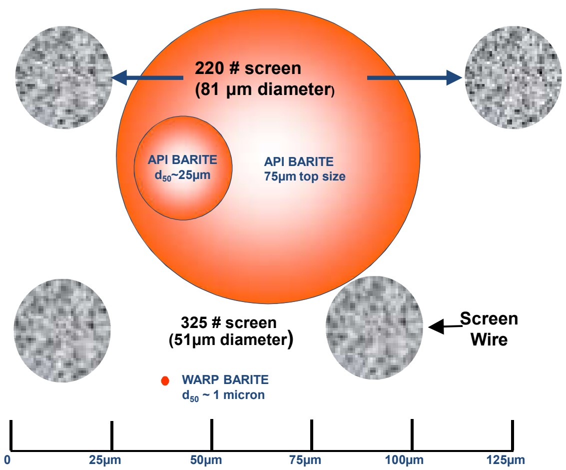
Smaller mesh Screens

Improves Solids
Removal Efficiency

Less regrinding
& recirculation

Less solids
build-up

LOWER DILUTION, LESS CONSUMPTION



Improves Solids
Removal Efficiency

Less Fluid
on cuttings

Drier
Cuttings

LESS WASTE, LOWER COST

RheGuard™

- Is a non-aqueous drilling fluid designed to deliver lower ECD contribution and lower Barite sag potential compared to conventional API Barite laden systems
- Includes MicroBar™, a micronized wieght material, allowing the use of existing pneumatically bulk transfer systems to tanks, boats and rigs
- Laboratory testing as well as field trials have shown that RheGuard™ will deliver low ECD by an improved rheology profile, better sag stability and similar fluid loss characteristics compared to conventional API Barite non-aqueous system

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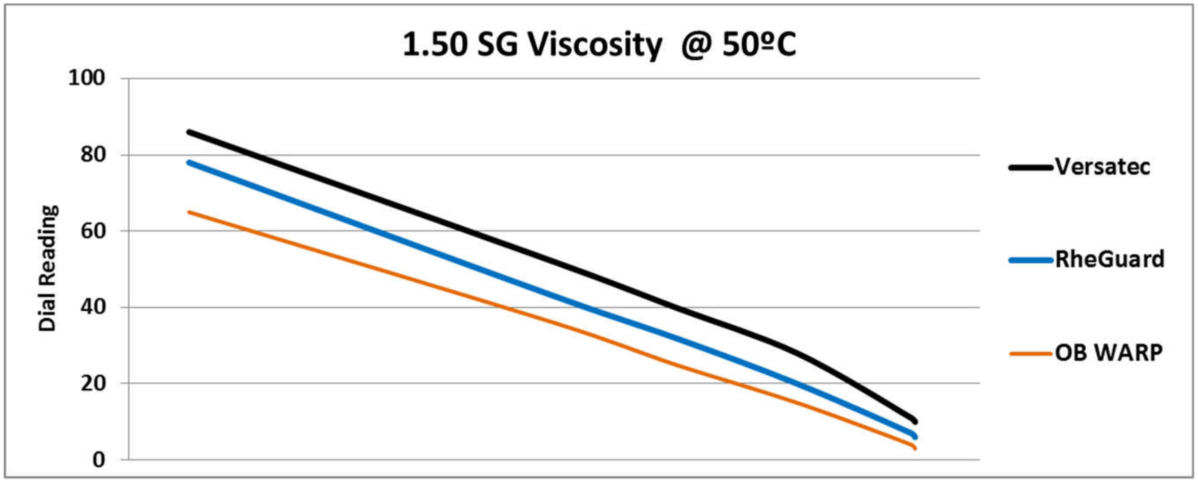
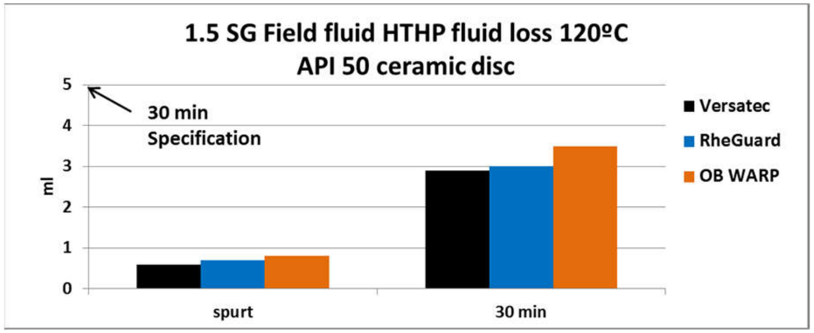
RheGuard™ Specifications from the lab qualification process

- Low viscosity profile PV optimization
- Low sag potential Δdyn sag < 0.04 SG
- Low and flat gel structure Δgel < 5 lbs/100ft²
- Good fluid loss control < 3 ml @ 30 min





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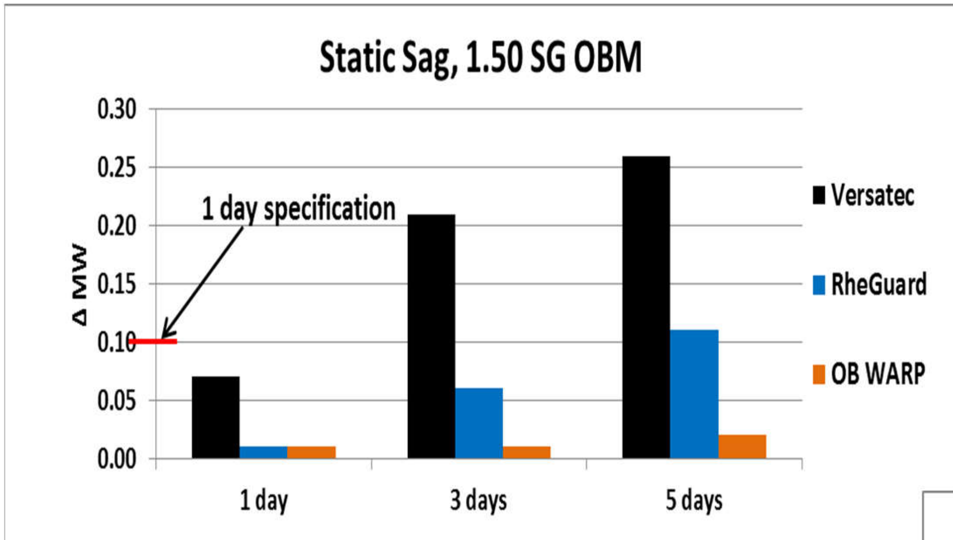
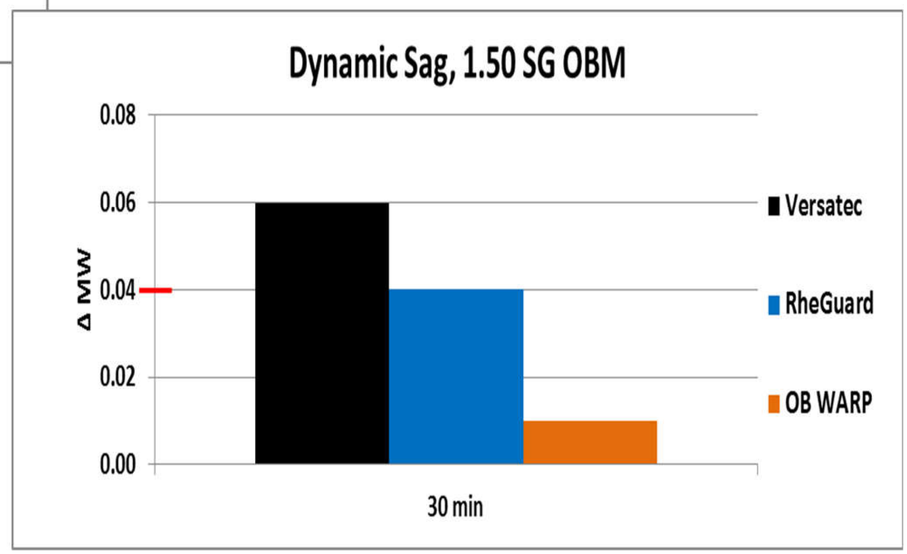
RheGuard™ Specifications from the lab qualification process





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Micronized Weight Material Technology – Improved sag stability

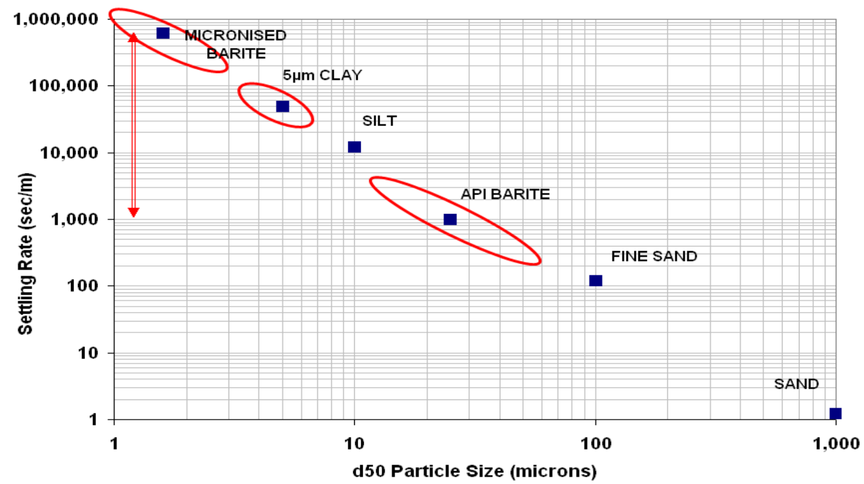
Stokes Law:

A 10 times reduction in particle size,

reduces settling rates by a 100

$$V_s = \frac{2}{9}\frac{(\rho_p - \rho_f)}{\eta} g\, R^2$$

Vs	settling velocity
ρp	particle density
ρf	fluid density
η	fluid viscosity
R	radius of particles



- Reduced risk of MW fluctuations
- Reduced risk of loss of hydrostatic column
- Reduced risk of dynamic sag with low circulation rates

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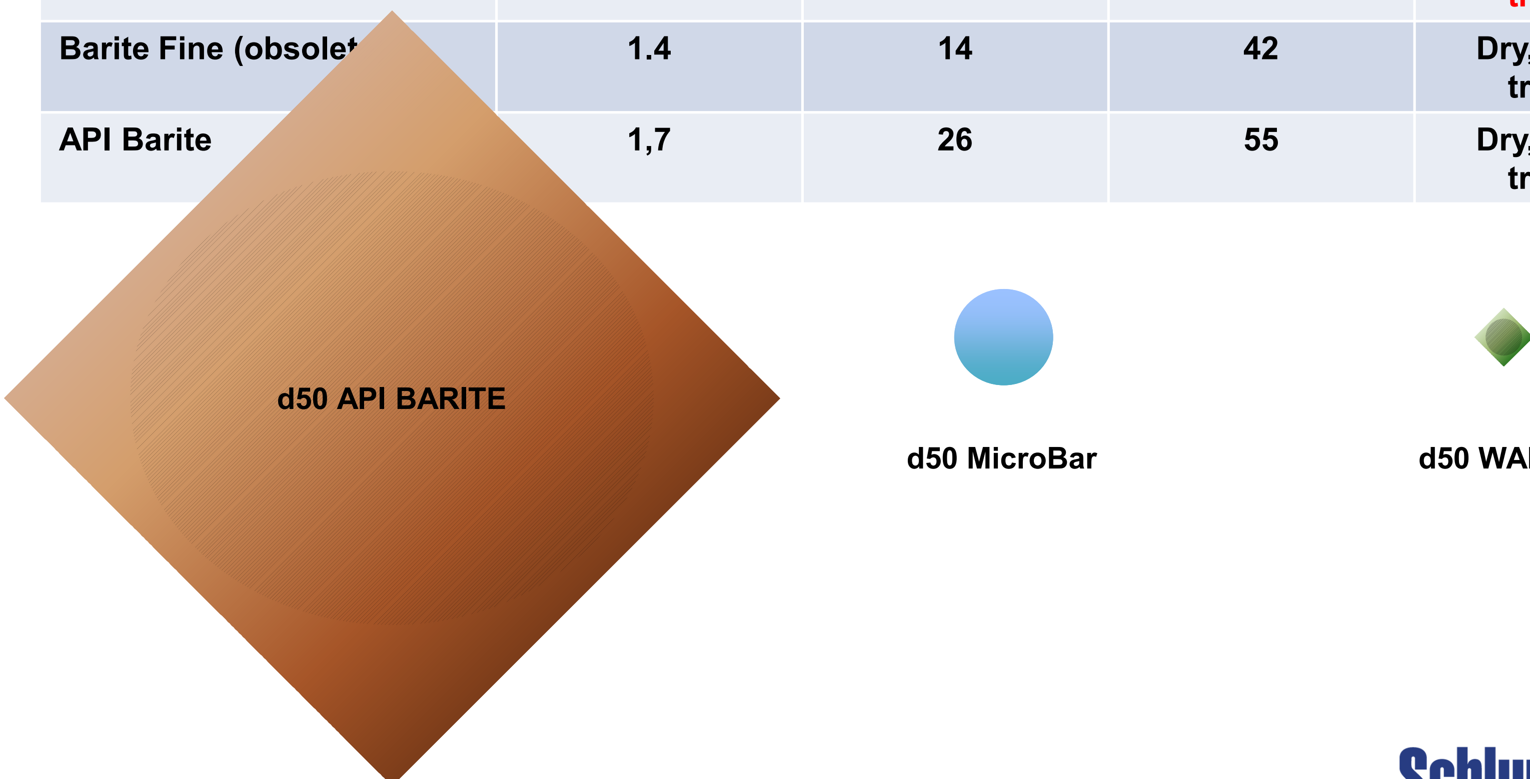
Particle size – weight materials

Weight Material	D10 [µm]	D50 [µm]	D90 [µm]	
WARP concentrate	0.6	1.6	7.8	Wet
MicroBar	1.0	5	21	Dry, pneum. transfer
Barite Fine (obsolet	1.4	14	42	Dry, pneum. transfer
API Barite	1,7	26	55	Dry, pneum. transfer



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Questions – Weighting materials

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